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IMPACT OF CLIMATE CHANGE ON PRECIPITATION FOR THE UPPER CAUVERY RIVER BASIN, KARNATAKA STATE

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ABSTRACT

Precipitation is the most important natural hydrologic event and is a unique phenomenon varying both in space and time. For the optimum development of water resources and for planning of agricultural operations in a given basin/region, basic knowledge of precipitation distribution during individual months, seasons and year is of vital importance. Hence, Rainfall trend and Standard Precipitation Index (SPI) anlysis was carried out for all 8 districts of Karnataka state falling under the upper Cauvery river basin. District-wise twelve months SPI maps were developed for the period of 63 years (1950 to 2012) by using annual average precipitation SPI values were computed. For the study area SPI values ranged from + 3.02 to – 2.88 indicating enormous variation in preicipition. Furher, from district-wise SPI maps for the period during 2001 to 2012, significant change in number of dry and wet years' occurrence was observed. Number of wet years increased in the districts of Bangalore Rural, Bangalore Urban and Kodagu while for the districts of Chamarajnagar, Hassan, Mandya, Mysore and Tumkur dry years were increased in recent decade. Mann–Kendall test was used for Statistical trend analysis to examine trends during the period (1901–2012) at the 5% level of significance. Both positive and negative trends were observed in rainfall events over upper Cauvery river basin.

KEYWORDS: Climate Change, SPI, Rainfall, Mann-Kendall Test, Trend Analysis

INTRODUCTION

Precipitation is the most important natural hydrologic event and is a unique phenomenon varying both in space and time. For the optimum development of water resources and for planning of agricultural operations in a given basin/region, basic knowledge of precipitation distribution during individual months, seasons and year is of vital importance. Past studies (IPCC, 2013, Sharma & Singh, 2007) have shown that global climate change has significant impact on water resources all over the world. The main cause factors for global climate change are enhanced greenhouse gas emissions, variation in net solar radiation received; changes in land use and land cover pattern, biotic processes, plate tectonics and volcanic eruption (Pandey et al. 2008). The fluctuations in weather pattern can lead to occurrence of hydro-meteorological extreme events like floods and droughts all over the world. In recent decades it has been found that frequency and magnitude of hydro-meteorological extreme events has increased significantly due to change in fluctuation of rainfall patterns and its distribution (IPCC, 2013, Sharma & Singh, 2007).

Karnataka state is the most vulnerable to hydro-meteorological extreme events in Indian subcontinent because of its wide variety of agro climatic zones and topography. In India, Karnataka is the second most natural disaster prone state in terms of geographical area. About 18 districts are drought prone and 4 districts are flood prone among 30 districts of the state. Since Karnataka is an agricultural-based state of India, rainfall plays an important role for fulfilment of water requirement in terms of agricultural as well as domestic purposes. So any change in rainfall from normal mean rainfall will have a significant impact on socio-economic conditions of the area. Krishnegouda (2011) studied the Rainfall analysis of Bhadra command area (Karnataka) for three major districts Shimoga, Davangere and Chikamagalore and found that rainfall in the region was showing a constantly rising trend mainly due to climate change and human interventions. However, there was still a gap of information to understand the rainfall fluctuation at a basin level of the state. So the study was taken up at basin level for the upper Cauvery river basin which comprising 8 districts of Karnataka. This paper reveals about the changes in the rainfall patterns of the region by developing the SPI at district-level and identifying the trend pattern of rainfall.

MATERIALS AND METHODS

The Cauvery river rises in the Western Ghats and flows eastward direction passing through the states of Karnataka, Tamil Nadu, Kerala and Pondicherry before draining into the Bay of Bengal. The basin lies between latitudes 100 05’ N and 130 30’ N and longitudes 750 30’ E and 790 45’ E. The total length of the river from source to its outfall into the Bay of Bengal is about 800 km. Of this, 320 km is in Karnataka, 416 km is in Tamil Nadu and 64 km forms the common boundary between Karnataka and Tamil Nadu states. The Cauvery basin extends over an area of 81,155 km2, which is nearly 24.7% of the total geographical area of the country. Among this total drainage area, Karnataka has 34273 km2 under the Cauvery basin. In the present study drainage area of upper Cauvery basin in Karnataka was considered “Figure 1”. This basin comprises Western Ghats and Mysore plateau. Among these, Western Ghats receive the highest annual rainfall (average 3638mm) and north Mysore plateau receives less rainfall compared to the state average annual rainfall of 1139 mm.

Data Used

For current study district-wise monthly precipitation data for period of 1901 to 2012 were collected from Indian water Portal site (http://indiawaterportal.org).

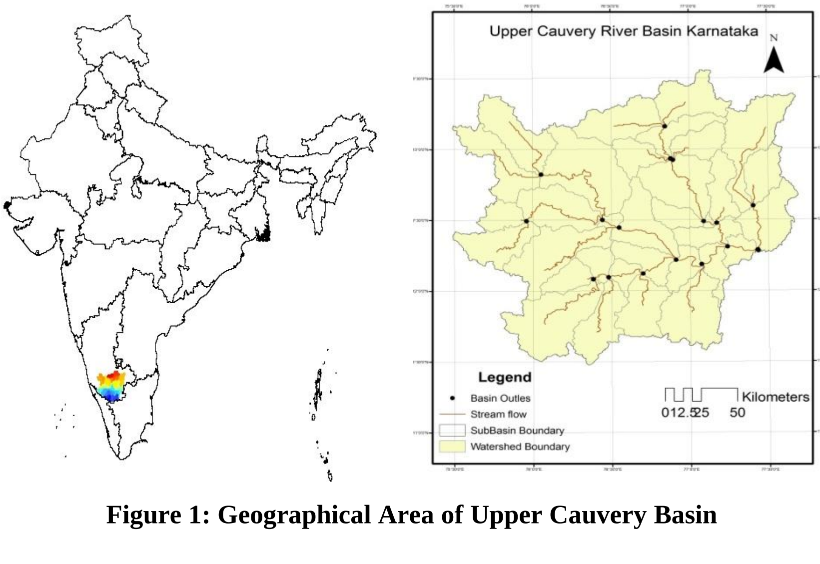


Figure 1: Geographical Area of Upper Cauvery Basin

Standard Precipitation Index

Standard precipitation index (SPI) is a probability based index, developed for better representation of abnormal wetness and dryness (Mckee 1993). In the present study, SPI was used for measuring drought severity as well as for analysing fluctuations of rainfall pattern. SPI is calculated by taking the difference of the precipitation from the mean for a particular time step and then dividing it by the standard deviation.

$$\text{SPI} = \frac{X_i - X_{avg}}{\sigma} \tag{1}$$

Where X_i is the actual precipitation, X_{avg} is the mean precipitation and σ is the standard deviation. For current study, SPI values for eight districtswere developed with time step 12 months by using the inverse distance squared weighting procedure of the Spatial and Time Series Information Modelling software package (SPATSIM, Institute for Water Research (IWR), Rhodes University, South Africa).

Mann–Kendall Test:

The Mann–Kendall (MK) test is a non-parametric test that can be used for detecting trends in a time series (Mann, 1945) where autocorrelation is non-significant. It has been found to be an excellent tool for trend detection to assess the significance of trends in hydro-meteorological time series data such as water quality, stream flow, temperature and precipitation (Santosh Pingale et. al 2011). TheM-K test can be applied to a time series x_i ranked from i = 1, 2, 3 … n -1 and x_j ranked from j = i + 1, 2, 3 … n such that:

$$\text{Sgn}\ (x_j - x_i) = \begin{cases} 1 \text{ if } (x_j - x_i) > 0 \\ 0 \text{ if } (x_j - x_i) = 0 \\ -1 \text{ if } (x_j - x_i) < 0 \end{cases} \tag{2}$$

The Kendall test statistic S can be computed as:

$$S = \sum_{k=1}^{n-1} \text{Sgn}\ (x_j - x_k) \tag{3}$$

Where $\text{sgn}(x_j - x_k)$ is the signum function. The test statistic S is assumed to be asymptotically normal, with E(S) = 0 for the sample size $n \geq 8$ and variance as follows:

$$\text{Var}(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)]}{18} \tag{4}$$

Where t_i denotes number of ties up to sample i.

The standardized M-K test statistic (Z_{mk}) can be estimated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases} \tag{5}$$

The standardized MK test statistic (Z_{mk}) follows the standard normal distribution with a mean of zero and variance of one. The presence of a statistically significant trend is evaluated using the Z_{mk} value. A positive (negative) value of Z_{mk} indicates an increasing (decreasing) trend. If $\pm Z_{mk} \leq Z_{\alpha/2}$ (here α = 0.1), then the null hypothesis for no trend is accepted in a two sided test for trend, and the null hypothesis for the no trend is rejected if$\pm Z_{mk} \geq Z_{\alpha/2}$. Failing to reject H_0 (i.e., null

hypothesis) does not mean that there is no trend.

RESULTS AND DISCUSSIONS

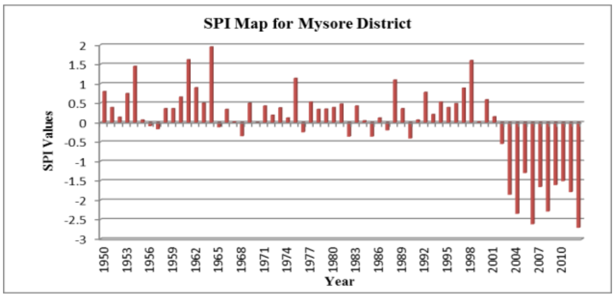
District-Wise SPI ANALYSIS

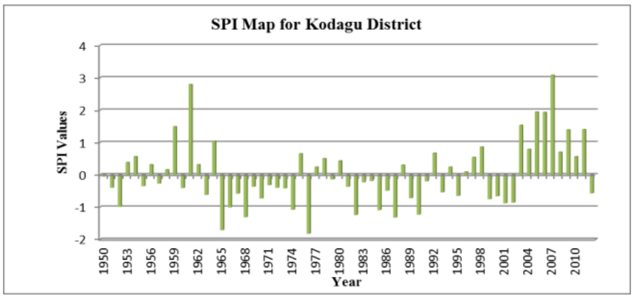
Monthly district-wise SPI maps were developed for the period during 1950 to 2012. Analysis showed that changing trend in rainfall pattern in the study area. From Table 1Results showed that there was an increase in rainfall amount in some districts, however, for the same time period other districts showed a decrease in rainfall. More specifically, rainfall in Kodagu, Bangalore Urban and Bangalore Rural received 0 to 25% increase in mean rainfall during last decade and the SPI values of these regions were more than 0 for most of the years. This meant that during last decade more wet years occurred in these districts. However, Mysore, Mandya, Chamrajanagara, Hassan and Tumkur districts experienced a rainfall deficit of about 20 to 57% from mean rainfall. By definition, if an area has rainfall deficiency of more than 10% that area is under meteorological drought, and if rainfall deficiency is up to 60%, it means that during last decade a continuous severe drought has occurred. In these districts there was huge impact on socio - economic communities, water dependent sectors and environment.

For the districts of Mysore, Mandya, Chamrajanagara, Hassan and Tumkur SPI results were homogeneous and ranged from -2.88 to 1.91. Mysore district SPI map “Figure 2” was used for detailed study. By the map it was found that before 2001 most of the SPI values were above zero and only nine dry years occurred even SPI value did not exceed more than -1. This indicated that there was occurrence of normal to wet years in Mysore from 1950 -2001. However, for the whole period from 2002 to 2012 SPI values were -1.31 to -2.72 suggesting that there was a continuous moderate to severe drought in the district. For the same time period (2001-2012), the Kodagu district showed an opposite trend as compared to Mysore. SPI values ranged from -0.68 to 3.08 suggesting that there was normal to very wet years occurred in the Kodagu “Figure 3”. However, during 2001 and 2012 rainfall increased about 10% because of increasing number of wet years in the last decade for Bangalore Urban District “Figure 4”. Overall, this analysis showed that both increase and decrease in rainfall amount in addition to a changing trend in the number of wet and dry years occurring in the study area.

Table 1: District-Wise Rainfall Analysis and SPI Value Range

Sl. No.	Name of District	Annual Mean Rainfall for the Period of 1901 to 2012	Annual Mean Rainfall for the Period of 2001 to 2012	Rainfall Deficiency From Mean	SPI Values for the Period of 1950 – 2012
1	Bangalore Rural	836	834	0	-2.48 to 2.43
2	Bangalore	850	925	9	-2.13 to 2.48
3	Chamarajanagar	1469	903	-39	-2.88 to 1.92
4	Hassan	2583	1293	-50	-2.87 to 2.35
5	Kodagu	2056	2540	24	-1.82 to 3.02
6	Mandya	1654	878	-47	-2.76 to 2.02
7	Mysore	2428	1045	-57	-2.72 to 1.98
8	Tumkur	998	801	-20	-2.40 to 2.01





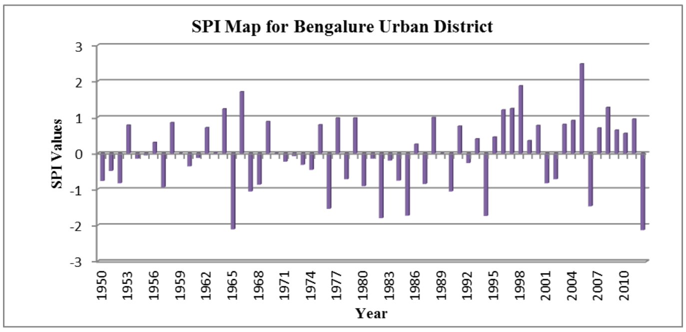


Figure 2, 3 & 4: Twelve Month SPI Maps

Mann–Kendall Test

The spatial distributions of trends in seasonal (monsoon) and annual average rainfall for the districts under upper Cauvery river basin viz., Bangalore Rural, Bangalore Urban, Chamarajanagar, Hassan, Kodagu, Mandya, Mysore and Tumkur were computed. The data set used was for the period of 1901 to 2012. The trends study was carried out at three different interval periods such as 1901 to 1940, 1941 to 1980 and 1981 to 2012 at 5% significance level. For the period 1901 to 1980 there was no trend, while for the period 1981 to 2012 both positive and negative trends were observed by the Mann-Kendall test "Table 2".

For the monsoon season there was no trend found in the districts of Bangalore Rural and Bangalore Urban. For the districts of Chamarajnagar, Hassan, Mandya, Mysore and Tumkur there was decrease in rainfall trend while for Kodagu increase in trend was observed. For the annual average rainfall, trend result showed increase in Kodagu, decrease in districts of Chamarajnagar, Hassan, Mandya and Mysore while for Bangalore Rural, Bangalore Urban and Tumkur no trend was observed.

Table 2: District Wise Mann-Kendle Z- Value for the Period of 1901 to 2012

Sl. No.	Name of District	1901-1940		1941-1980		1981-2012	
		Monsoon	Annual Mean	Monsoon	Annual Mean	Monsoon	Annual Mean
1	Bangalore Rural	-0.45	0.01	0.50	0.34	0.15	0.73
2	Bangalore	-0.66	-0.01	0.27	0.34	0.83	1.86
3	Chamarajanagar	-1.71	-1.43	-0.10	-0.06	-3.68	-2.84
4	Hassan	-0.59	-0.73	-1.22	-1.50	-3.42	-3.16
5	Kodagu	-0.71	-0.83	-0.48	-0.48	2.48	3.00
6	Mandya	-0.69	-0.69	-0.83	-1.11	-3.49	-3.00
7	Mysore	-0.78	-0.66	-0.43	-0.41	-3.39	-3.03
8	Tumkur	-0.36	-0.08	0.34	0.24	-2.35	-1.02

CONCLUSIONS

In the upper Cauvery river basin, there was a huge impact of climate change on rainfall patterns as well as socio-economic condition of the people. For Upper Cauvery river basin usually the drought intensity was once in four years barring Kodagu district. But due to climate change some of the districts are subjected to continuous drought over a period of more than ten years. The districts under continuous drought (Mysore, Hassan, Mandya, and Chamarajanagar) experienced a rainfall deficiency of more than 20 % from normal during period of 2001 to 2012. During the same period, Bangalore Rural, Bangalore Urban and Kodagu districts received 0 – 24 % more rainfall than the normal rainfall. The trend analysis gave both increase and decrease trend for the period during 1981 to 2012. But 1901 to 1980 there was no trend observed for the rainfall in the upper Cauvery river basin. Finally, due to impact of global climate change, it was concluded that the fluctuation of rainfall pattern from the normal rainfall, both decrease and increase in rainfall was projected in the study area.

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